NACA

RESEARCH MEMORANDUM

LATERAL-CONTROL INVESTIGATION OF FLAP-TYPE AND SPOILER-TYPE CONTROLS ON A WING WITH QUARTER-CHORD-LINE SWEEPBACK OF 60°, ASPECT RATIO 2, TAPER RATIO 0.6, AND NACA 65A006 AIRFOIL SECTION

TRANSONIC-BUMP METHOD

By Alexander D. Hammond

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
July 18, 1950

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

LATERAL-CONTROL INVESTIGATION OF FLAP-TYPE AND SPOILER-TYPE CONTROLS ON A WING WITH QUARTER-CHORD-LINE SWEEPBACK OF 60°, ASPECT RATIO 2, TAPER RATIO 0.6, AND NACA 65A006 AIRFOIL SECTION

TRANSONIC-BUMP METHOD

By Alexander D. Hammond

SUMMARY

As a part of an NACA research program, an investigation by the transonic-bump method through a Mach number range of 0.6 to 1.15 has been made in the Langley high-speed 7- by 10-foot tunnel to determine the lateral-control characteristics of a semispan wing-fuselage combination equipped with flap-type and spoiler-type controls. The wing of the semispan wing-fuselage combination had 60° of sweepback of the quarter-chord line, an aspect ratio of 2.0, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free stream. The flap-type controls were 30-percent-chord controls and the spoiler-type controls had a projection of 5 percent of the local wing chord and were located along the 70-percent-chord line; each type of control had various spans and spanwise locations on the wing semispan.

Both the flap-type and spoiler-type controls of the present investigation will provide lateral control throughout the Mach number range investigated. In general, the effectiveness of flap-type controls decreased as the Mach number increased from 0.80 to 1.05, whereas the effectiveness of spoiler-type controls increased with increase in Mach number in the same region.

INTRODUCTION

The need for aerodynamic data in the transonic-speed range has led to the establishment of an integrated program for transonic research.

As part of the NACA transonic research program, a series of wing-fuselage configurations, having wing plan forms as the only variable, are being investigated in the Langley high-speed 7- by 10-foot tunnel by using the transonic-bump method.

The purpose of this investigation was to obtain lateral-control data for flap-type controls and spoiler-type controls. This paper presents the results of a lateral-control investigation of a semispan wing-fuselage model employing a wing with quarter-chord line swept back 60°, an aspect ratio of 2.0, taper ratio 0.6, and an NACA 65A006 airfoil section parallel to the free air stream. The flap-type controls were 30-percent-chord controls; the spoiler-type controls were located along the 70-percent-chord line and had a projection of 5 percent of the local wing chord; each control had various spans and spanwise locations. The results of a previous investigation of the same wing-fuselage configuration without controls may be found in reference 1.

MODEL AND APPARATUS

The semispan wing had 60° of sweepback of the quarter-chord line, an aspect ratio of 2.0, and an NACA 65A006 airfoil section (reference 2) parallel to the free air stream (fig. 1). The semispan wing was made of beryllium copper, and the fuselage and spoiler ailerons were made of brass with all surfaces polished. The wing was mounted vertically in the center of the fuselage with no dihedral or incidence. The fuselage used in this investigation was semicircular in cross section and conformed to the ordinates given in reference 1.

The flap-type controls were made integral with the wing by cutting grooves 0.03-inch wide along the 70-percent-chord line on the upper and lower surfaces of the wing (fig. 2(a)). The entire control from fuselage to wing tip was divided into four equal spanwise segments (fig. 2(a)), each having a span of $0.20\frac{b}{2}$. After setting the control at the desired deflection by bending the metal along the grooves, the grooves and gaps were filled with wax, thus giving a close approach to a 30-percent-chord sealed plain flap-type control surface.

The plain spoiler-type controls consisted of spoiler segments, each having a span of $0.20\frac{b}{2}$ and a projection of 5 percent of the local wing chord, attached to the upper surface of the wing along the 70-percent-chord line (fig. 2(b)). The spoiler ailerons were made from 1/32 inch sheet brass and were mounted in such a manner that the faces of the ailerons were normal to the wing surface. The simulated actuating arms

used for one configuration were triangular in shape and made of sheet brass. The actuating arms were mounted $0.10\frac{b}{2}$ apart normal to the face of the spoiler ailerons and the upper surface of the wing.

The model was mounted on an electrical strain-gage balance wired to a calibrated galvanometer in order to measure the aerodynamic forces and moments. The balance was mounted in a chamber within the bump, and the chamber was sealed except for a small rectangular hole through which an extension of the wing passed. This hole was covered by the fuselage end plate which was approximately 0.06 inch above the bump surface.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient $\left(\frac{\text{Twice lift of semispan model}}{qS}\right)$

C_D drag coefficient $\left(\frac{\text{Twice drag of semispan model}}{qS}\right)$

C_m pitching-moment coefficient referred to $0.25\bar{c}$ $\left(\frac{\text{Twice pitching moment of semispan model}}{qS\bar{c}}\right)$

C_l rolling-moment coefficient at the plane of symmetry corrected for reflection-plane effects (L/qSb)

C_{l_u} uncorrected rolling-moment coefficient

C_n yawing-moment coefficient (N/qSb)

Δ increment caused by aileron projection or deflection

q effective dynamic pressure over span of model, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

L rolling moment of semispan model due to aileron deflection or projection, foot pounds

N yawing moment of semispan model due to aileron deflection or projection, foot pounds

S twice wing area of semispan model, 0.125 square foot

$\bar{c}$ mean aerodynamic chord of wing, 0.255 foot $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

c local wing chord, feet

y spanwise distance from plane of symmetry

y_i spanwise distance from plane of symmetry to inboard end of control

y_o spanwise distance from plane of symmetry to outboard end of control

ρ mass density of air, slugs per cubic foot

V free-stream air velocity, feet per second

M effective Mach number over span of model

M_a average chordwise local Mach number

M_l local Mach number

R Reynolds number of wing based on $\bar{c}$

α angle of attack, degrees

δ control deflection relative to wing-chord plane, measured perpendicular to control hinge axis (positive when trailing edge is down), degrees

b twice span of semispan model, 0.5 foot

b_a control span measured perpendicular to plane of symmetry, feet

$$C_{L_\delta} = \left(\frac{\partial C_L}{\partial \delta}\right)_\alpha$$

$$C_{l_\delta} = \left(\frac{\partial C_l}{\partial \delta}\right)_\alpha$$

$$C_{m_\delta} = \left(\frac{\partial C_m}{\partial \delta}\right)_\alpha .$$

The subscript α indicates that the angle of attack was held constant.

CORRECTIONS

The aileron-effectiveness parameters of the flap-type ailerons and the rolling-moment coefficients of the spoiler-type ailerons presented herein represent the aerodynamic effects on a complete wing produced by the deflection or projection, respectively, of the control on only one semispan of the complete wing. Reflection-plane corrections have been applied to the data throughout the Mach range tested. The reflection-plane corrections which were applied to the rolling-moment coefficients of the flap-type and spoiler-type controls are given in figure 3. The values of the corrections given in figure 3 were obtained from unpublished experimental low-speed data and theoretical considerations and are valid for low Mach numbers only, but it was believed that applying the corrections at high Mach numbers would give a better representation of true conditions than uncorrected data.

The lift and pitching-effectiveness parameters represent the aerodynamic effects of deflection in the same direction of the controls on both semispans of the complete wing, and, hence, no reflection-plane corrections are necessary for the lift and pitching-moment data.

No corrections were applied for any twisting or deflection of the wing caused by air load imposed by flap deflection. Based on static tests made on the wing, these effects were found to be within experimental accuracy of setting the flap.

TEST TECHNIQUE

The tests were made in the Langley high-speed 7- by 10-foot tunnel using an adaptation of the NACA wing-flow technique for obtaining transonic speeds. The technique used involves placing the model in the high-velocity flow field generated over the curved surface of a bump on the tunnel floor (reference 3).

Typical contours of local Mach number in the vicinity of the model location on the bump with model removed are shown in figure 4. The contours indicate that there is a Mach number variation of about 0.03 over the wing semispan at low Mach numbers and about 0.04 at high Mach numbers. The chordwise Mach number variation is generally less than 0.01. Because of these two effects the effective Mach number over the wing semispan is estimated to be 0.02 higher than the effective Mach number where 50-percent-span outboard ailerons normally would be located. No attempt has been made to evaluate the effects of this chordwise and spanwise Mach number variation. The long-dashed lines in figure 4 indicate a local Mach number 5 percent below the maximum value and

represent the estimated extent of the bump boundary layer. The effective test Mach number was obtained from contour charts similar to those presented in figure 4 by using the relationship

$$M = \frac{2}{S}\int_0^{b/2} cM_a \, dy$$

The variation of mean test Reynolds number with Mach number is shown in figure 5. The boundaries on the figure are an indication of the probable range in Reynolds number caused by variations in test conditions during the course of the investigation.

Force and moment data were obtained with 30-percent-chord flap-type controls having various spans and spanwise locations through a Mach number range of 0.70 to 1.15, an angle-of-attack range of -8° to 8°, for control deflections of 0° and 10°.

Force and moment data were obtained with the spoiler ailerons having various spans and spanwise locations through a Mach number range of 0.60 to 1.15 and an angle-of-attack range of 0° to 8°. The spoiler ailerons were projected 5 percent of the local wing chord and were located along the 70-percent-chord line. In addition, tests were made through the Mach number range and angle-of-attack range of a $0.60\frac{b}{2}$ inboard spoiler aileron with simulated actuating arms.

RESULTS AND DISCUSSION

Lateral-Control Characteristics of Flap-Type Controls

In figures 6 to 8 are curves of lift, aileron- and pitching-effectiveness parameters plotted against Mach number for flap-type controls having various spans and spanwise locations on the semispan wing-fuselage combination. The flap-type control-effectiveness parameters presented in figures 8 to 10 were obtained from curves of lift, rolling- and pitching-moment coefficients plotted against control deflection, at deflections of -10°, 0°, and 10°, for each configuration tested. Inasmuch as the wing was symmetrical, data obtained at negative angles of attack and $+10^\circ$ deflection were considered, with due regard to sign, to be equivalent to data that would be obtained at positive angles of attack and -10° deflection.

A slight decrease in aileron and lift effectiveness occurs between Mach numbers of 0.80 to 1.05 for most configurations, and a relatively

smaller decrease in the negative values of pitching-effectiveness parameter occurs in the same region (figs. 6 to 8).

The effectiveness of controls of various spans (fig. 7) indicates that the outboard 40-percent-span control gives relatively low aileron effectiveness when compared to an inboard control $\left(0.20\frac{b}{2} \text{ to } 0.60\frac{b}{2}\right)$ of 40 percent span. The center control $\left(0.40\frac{b}{2} \text{ to } 0.80\frac{b}{2}\right)$ of 40 percent span gives even higher aileron effectiveness than the inboard control throughout the Mach number range.

The aileron effectiveness of flap-type controls of various spans starting at the tip (fig. 9) indicates that although there are considerable differences in aileron effectiveness of a given span control with increasing Mach number, in general, the curves have the same shape. This would indicate that the relative effectiveness of a partial-span control to a full-span control is little affected by Mach number. This result agrees with previous results found for 30-percent-chord flap-type controls on a series of wings (references 4 to 7) having 0°, 35°, 45°, and 60° of sweepback of the quarter-chord line and having an aspect ratio of 4, taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the root chord line. The pitching-effectiveness data (figs. 8 and 9) show very little change with Mach number except at supersonic Mach numbers where a loss in effectiveness occurs for all control spans.

The experimental values of C_{l_δ} for $M = 0.70$ and 0.80 are compared in figure 10 with the theoretical values of C_{l_δ} for $M \longrightarrow 0$ estimated by the methods of reference 8. The results show good agreement for outboard flap-type controls having spans up to $0.40\frac{b}{2}$, but the results are somewhat higher than theory for larger spans.

Lateral-Control Characteristics of Spoiler-Type Controls

The characteristics of the semispan wing-fuselage combination equipped with spoiler-type controls having various spans and spanwise locations are presented in figures 11 to 15.

The incremental rolling- and yawing-moment coefficients for spoiler ailerons having various span and spanwise locations are presented in figures 12 and 14. There was an increase in rolling-moment coefficient with increase in Mach number in the Mach number region of 0.6 to 1.1 for all spoiler-type controls except for the 0.20-span outboard spoiler-type control in which the increase was noted in the Mach region of 0.9 to 1.1 (figs. 12 and 14). The rolling-moment coefficients generally increased

as a constant 40-percent-span aileron was moved from outboard to inboard (figs. 12, 14, and 15). As the span of an outboard or inboard spoiler was increased, the rolling moments generally increased except for an angle of attack of 8° for which a 60-percent inboard spoiler aileron produced higher values of rolling-moment coefficient than an 80-percent inboard spoiler aileron throughout the Mach range tested (figs. 12 and 14). The effect of span and spanwise location on the rolling-moment coefficients of spoiler ailerons presented in the low-speed investigation of reference 9 show results that are similar in trend to the results of the present investigation. The addition of simulated actuating arms to the 60-percent-inboard spoiler aileron produced a slight increase in rolling effectiveness at 0° and 4° angle of attack and produced an even greater increase in rolling effectiveness at 8° angle of attack (fig. 14).

In order to provide some information on the characteristics of the spoiler-type controls when used as speed brakes or glide-path controls, either alone or while simultaneously functioning as ailerons, the incremental effects of the various spoiler-aileron configurations on the lift, drag, and pitching moment are presented in figures 11 and 13. These are the effects produced by the spoiler-ailerons projected simultaneously on both semispans of the complete wing. It is seen that, in most cases, the incremental lift, drag, and pitching moment increase with increase in span of either outboard or inboard spoiler ailerons. In the Mach number range from 0.6 to 1.0 the incremental lift and pitching moment usually increased with increase in Mach number and a marked decrease in lift occurred above a Mach number of 1.00. However, in general, the incremental drag decreases with increase in Mach number throughout the Mach number range tested. A comparison of the incremental drag coefficient based on the projected area of the spoiler aileron of the present investigation with two types of fuselage brakes of reference 10 shows that the spoiler aileron gave an increment in drag coefficient of 2.00, whereas the fuselage brakes gave an incremental drag coefficient of 1.04 when extended from the side and 0.62 when extended from the bottom.

The yawing-moment coefficients of the spoiler-type ailerons were generally found to be favorable for all configurations throughout the Mach range investigated.

Comparison of Flap-Type and Spoiler-Type Controls

A comparison of the rolling-moment coefficients of a 40-percent-span, 30-percent-chord midspan flap-type aileron at two deflections and a 60-percent-span inboard spoiler-type aileron is shown in figure 16. For purposes of comparison, the signs of the rolling-moment coefficients of the two types of ailerons were made to agree. In general, the rolling-moment coefficients of the flap-type ailerons decreased as the Mach number increased, while the rolling-moment coefficient of the

spoiler-type aileron increased with Mach number. The rolling-moment coefficients of the spoiler aileron are less than those of the flap-type aileron having a total deflection of 20° and generally about equal to or greater than those of the flap-type ailerons having a total deflection of 10° throughout the Mach number range investigated (fig. 16).

The yawing-moment coefficients of the spoiler-type ailerons were favorable for all configurations throughout the Mach number range investigated. Although the yawing-moment coefficients were not measured for the flap-type controls, they have been found to be generally unfavorable in previous investigations.

In general, smaller wing-twisting moments are produced by spoiler-type ailerons than flap-type ailerons; hence higher reversal speeds due to wing twist are obtained on wings equipped with spoiler-type controls (figs. 9 and 15).

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

REFERENCES

1. Myers, Boyd C., II, and King, Thomas J., Jr.: Aerodynamic Characteristics of a Wing with Quarter-Chord Line Swept Back 60°, Aspect Ratio 2, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L50A12, 1950.

2. Loftin, Laurence K., Jr.: Theoretical and Experimental Data for a Number of NACA 6A-Series Airfoil Sections. NACA Rep. 903, 1948.

3. Schneiter, Leslie E., and Ziff, Howard L.: Preliminary Investigation of Spoiler Lateral Control on a 42° Sweptback Wing at Transonic Speeds. NACA RM L7F19, 1947.

4. Hammond, Alexander D.: Lateral-Control Investigation of Flap-Type Controls on a Wing with Unswept Quarter-Chord Line, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L50A03, 1950.

5. Thompson, Robert F.: Lateral-Control Investigation of Flap-Type Controls on a Wing with Quarter-Chord Line Swept Back 35°, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L9L12a, 1950.

6. Vogler, Raymond D.: Lateral-Control Investigation of Flap-Type Controls on a Wing with Quarter-Chord Line Swept Back 45°, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L9F29a, 1949.

7. Vogler, Raymond D.: Lateral-Control Investigation of Flap-Type Controls on a Wing with Quarter-Chord Line Swept Back 60°, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L50A17, 1950.

8. Lowry, John G., and Schneiter, Leslie E.: Estimation of Effectiveness of Flap-Type Controls on Sweptback Wings. NACA TN 1674, 1948.

9. Fischel, Jack, and Hammond, Alexander D.: Investigation of Effect of Span and Spanwise Location of Plain and Stepped Spoiler Ailerons on Lateral Control Characteristics of a Wing with Leading Edge Swept Back 51.3°. NACA RM L9K02, 1950.

10. Stephenson, Jack D.: The Effects of Aerodynamic Brakes upon the Speed Characteristics of Airplanes. NACA TN 1939, 1949.

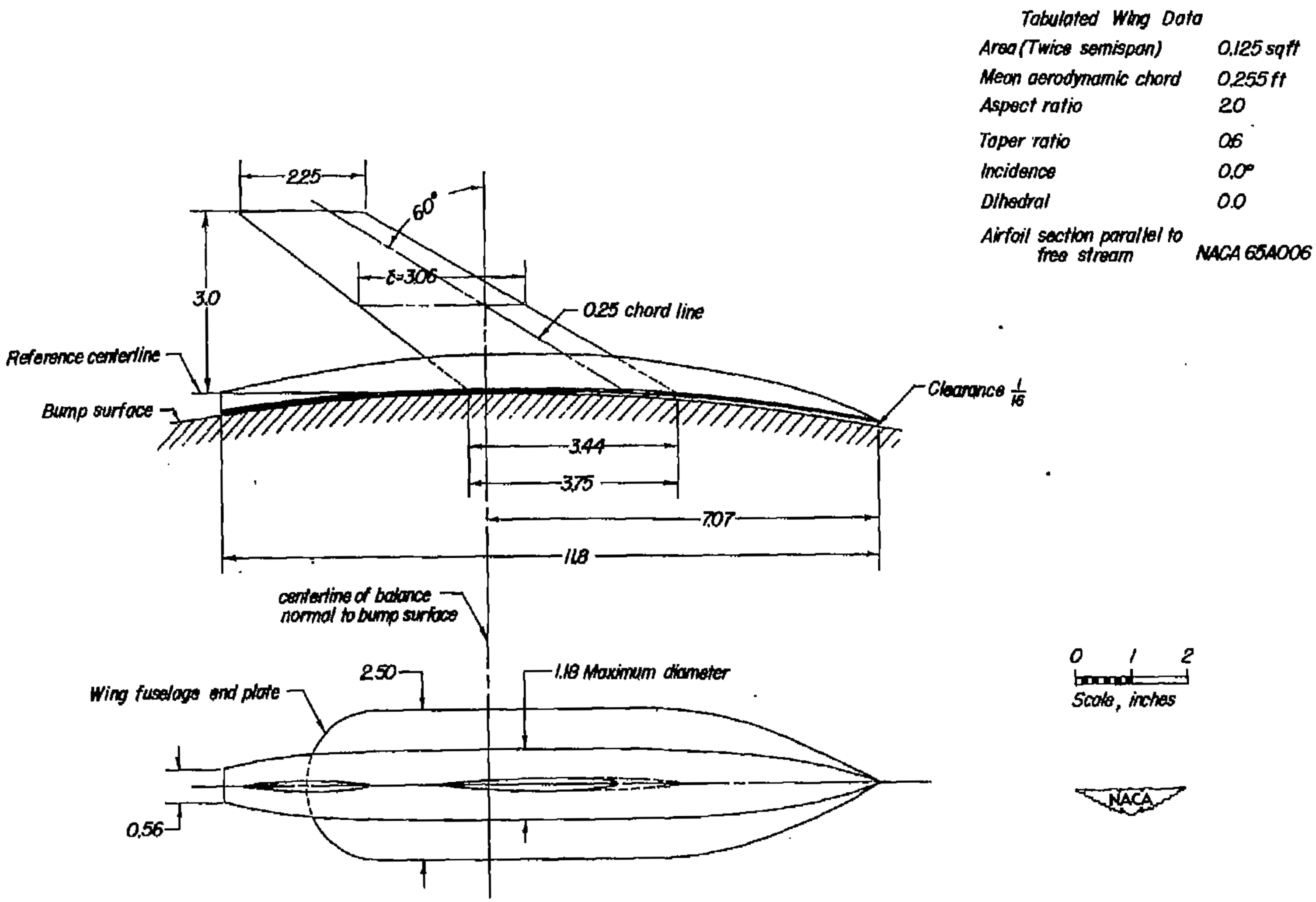
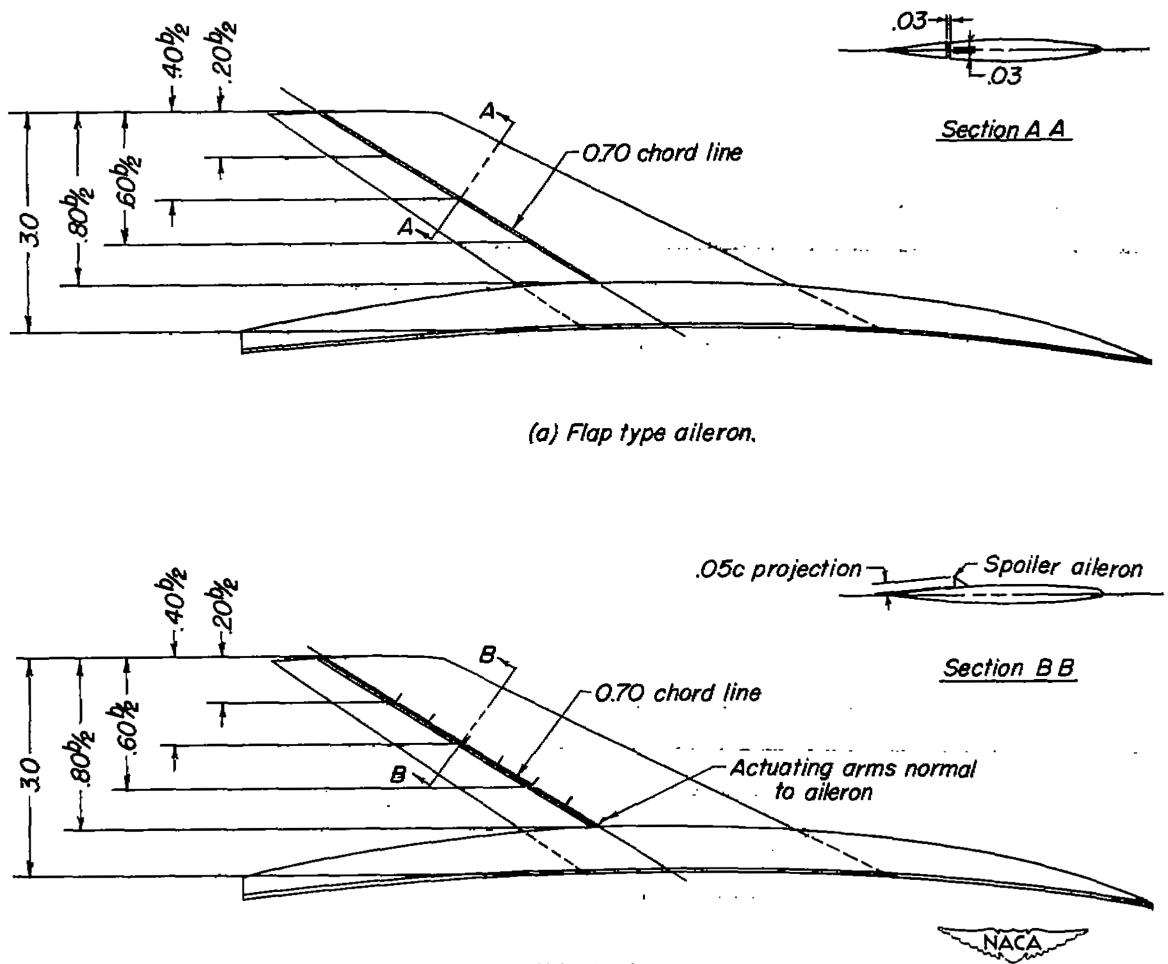


Figure 1.- General arrangement of model with 60° sweptback wing, aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil.



(a) Flap type aileron.

(b) Spoiler aileron.

Figure 2.- Details of control arrangements.

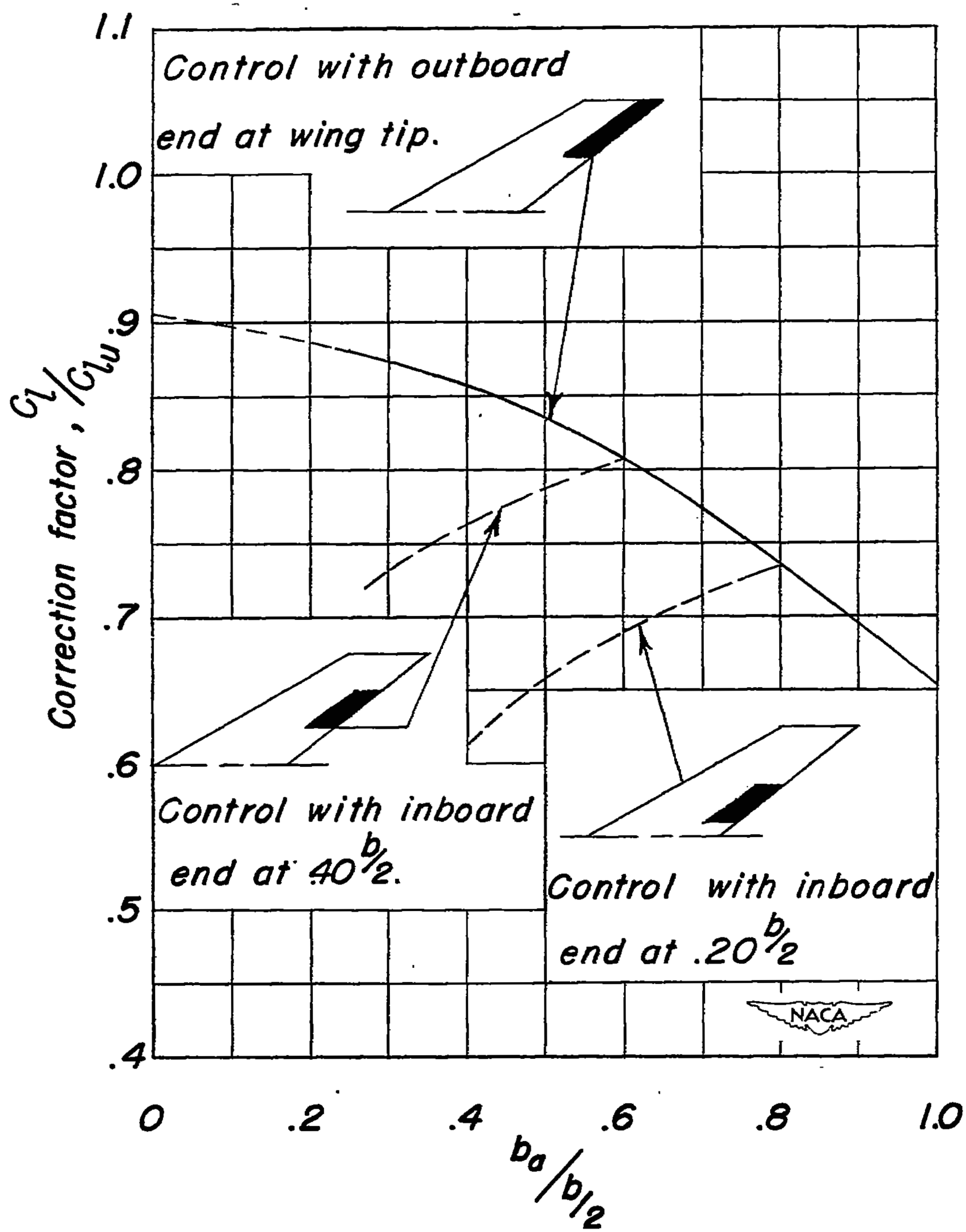


Figure 3.- Reflection-plane correction factors for inboard, center, and outboard controls of various spans for a wing of 60° of sweepback, aspect ratio 2, and taper ratio of 0.6.

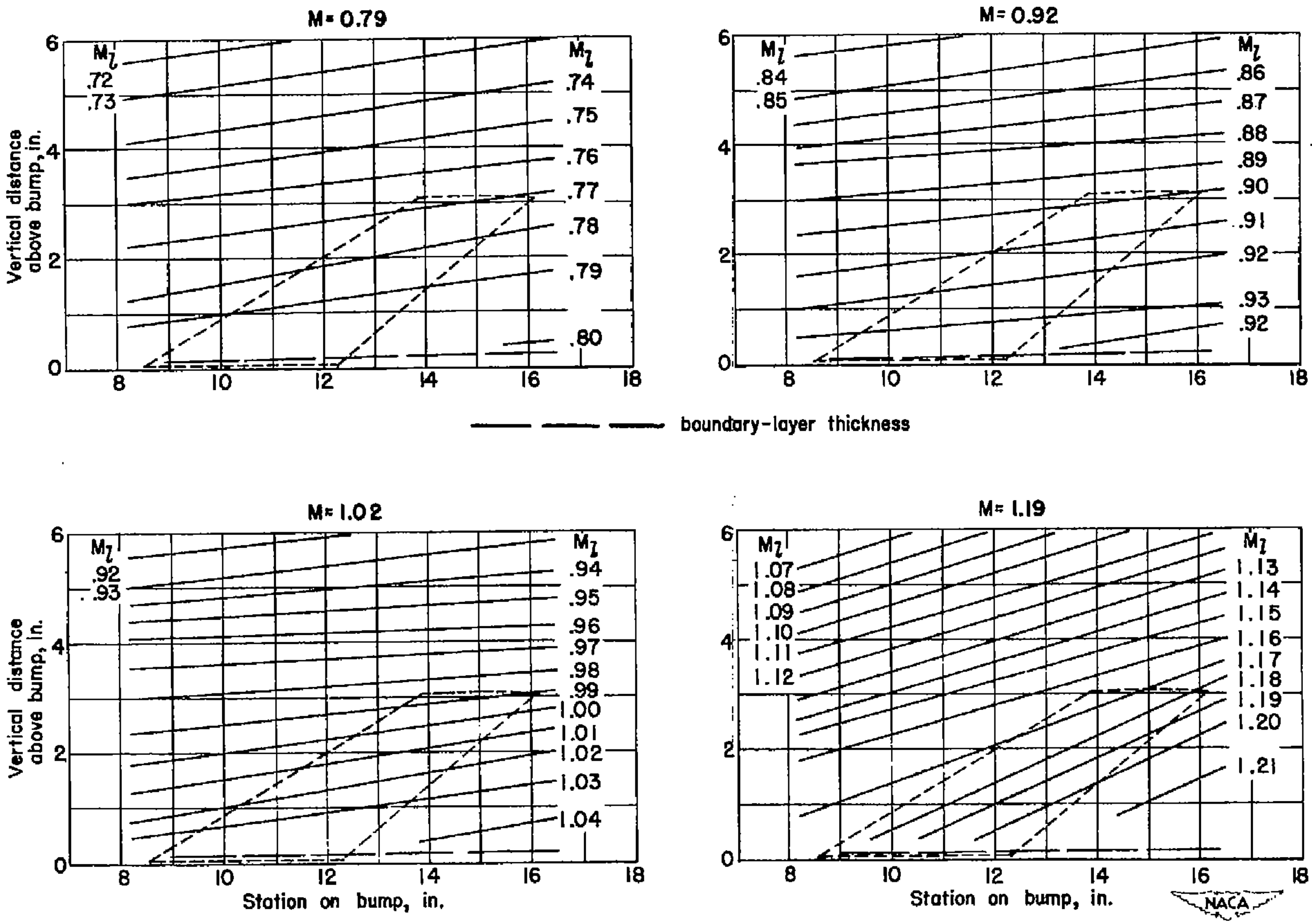


Figure 4.- Typical Mach number contours over transonic bump in region of model location.

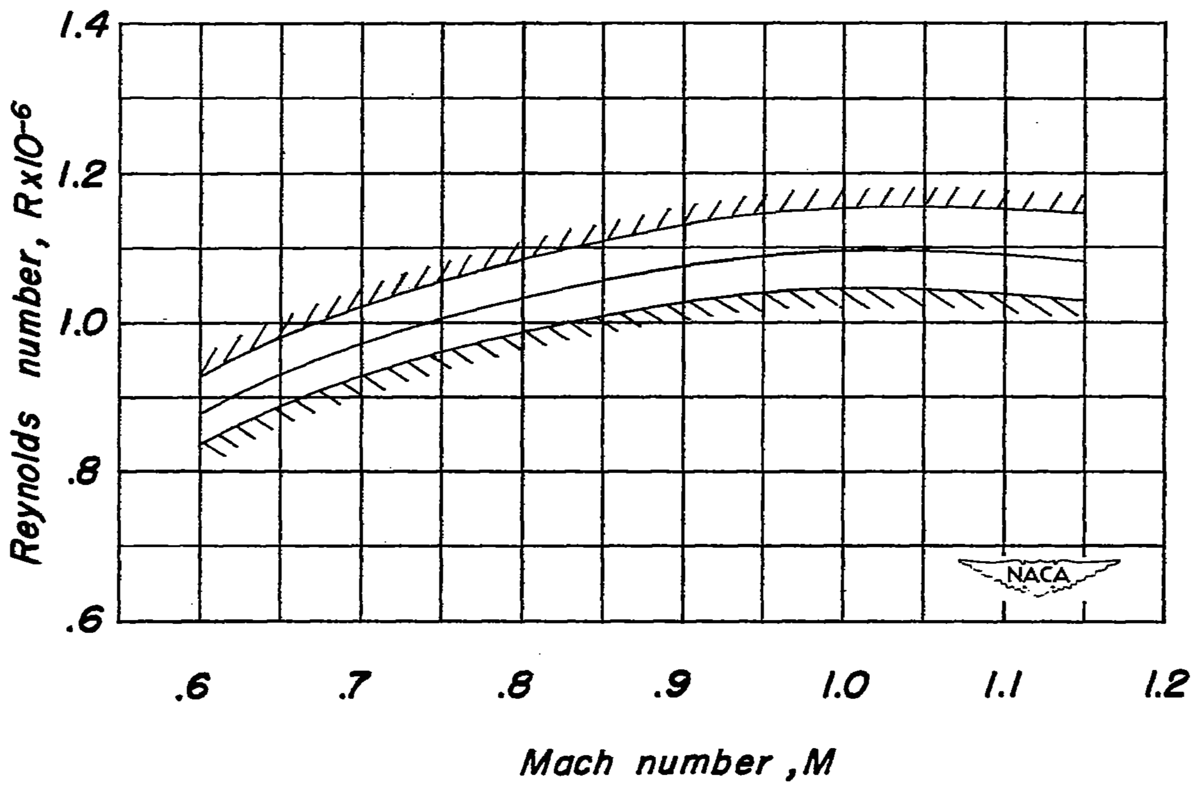


Figure 5.- Variation of test Reynolds number with Mach number for model with 60° sweptback wing, aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil.

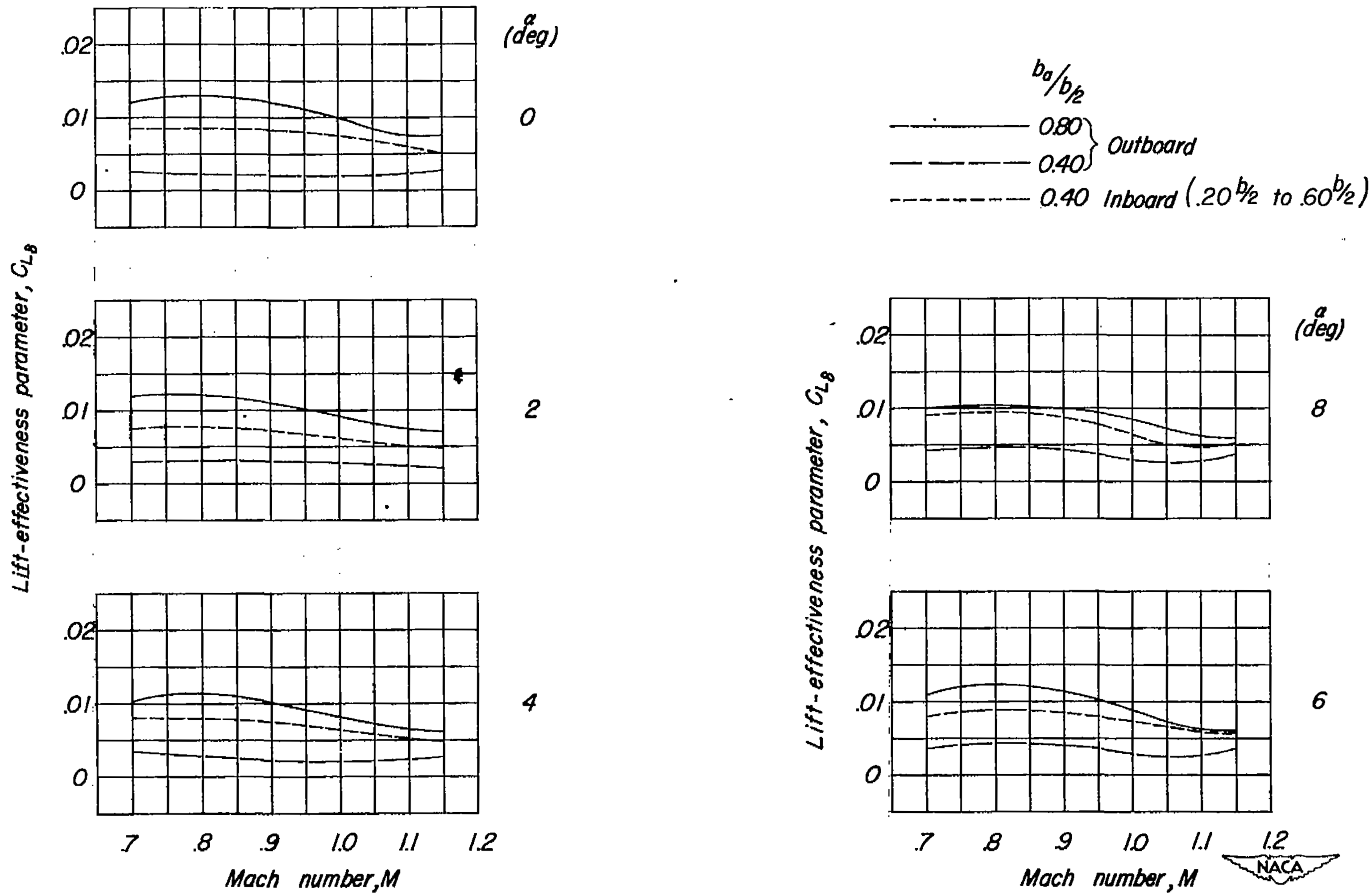


Figure 6.- Variation of lift-effectiveness with Mach number for flap-type controls on a 60° sweptback wing with aspect ratio 2, taper ratio 0.6 and NACA 65A006 airfoil.

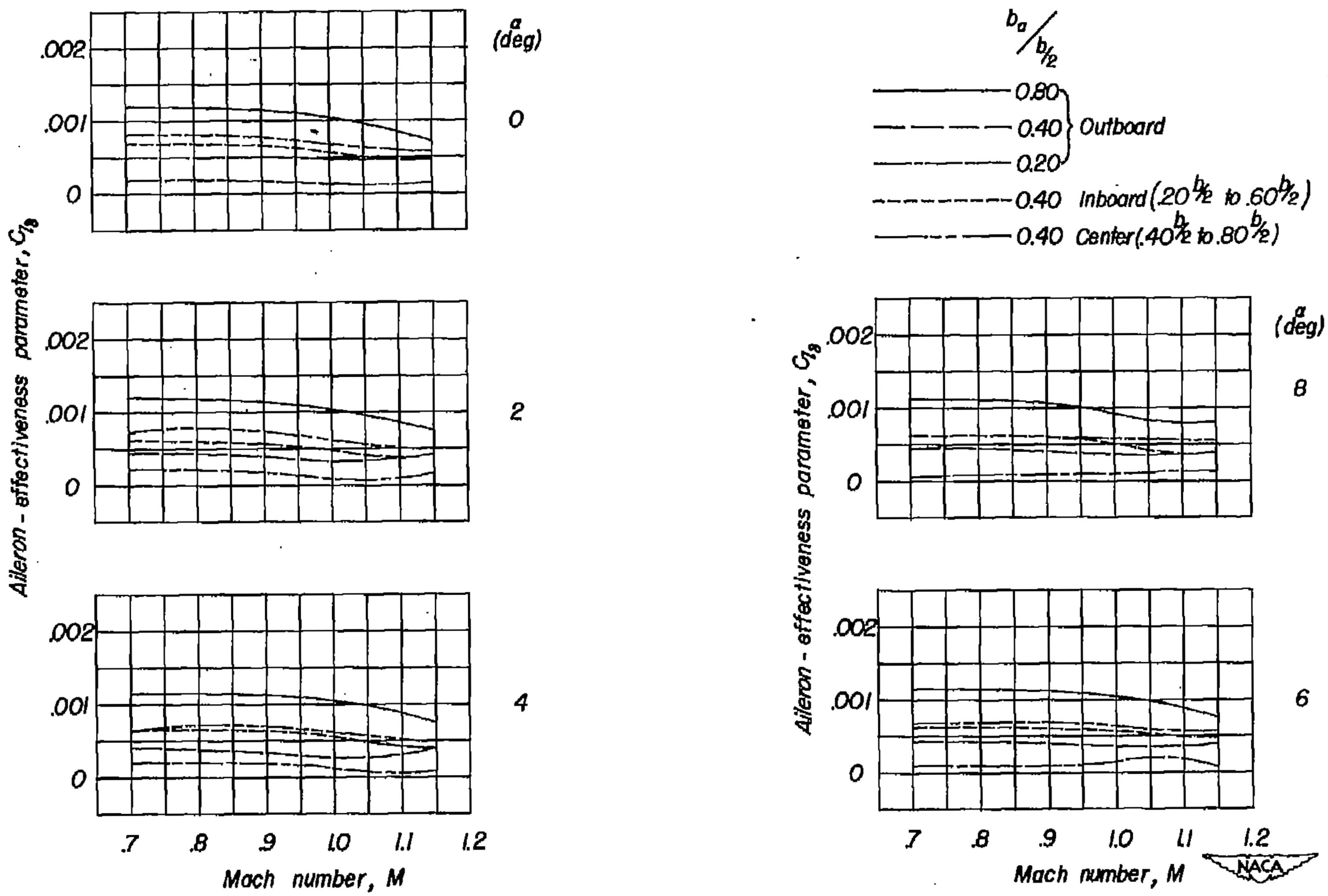


Figure 7.- Variation of aileron effectiveness with Mach number for flap-type controls on a 60° sweptback wing with aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil.

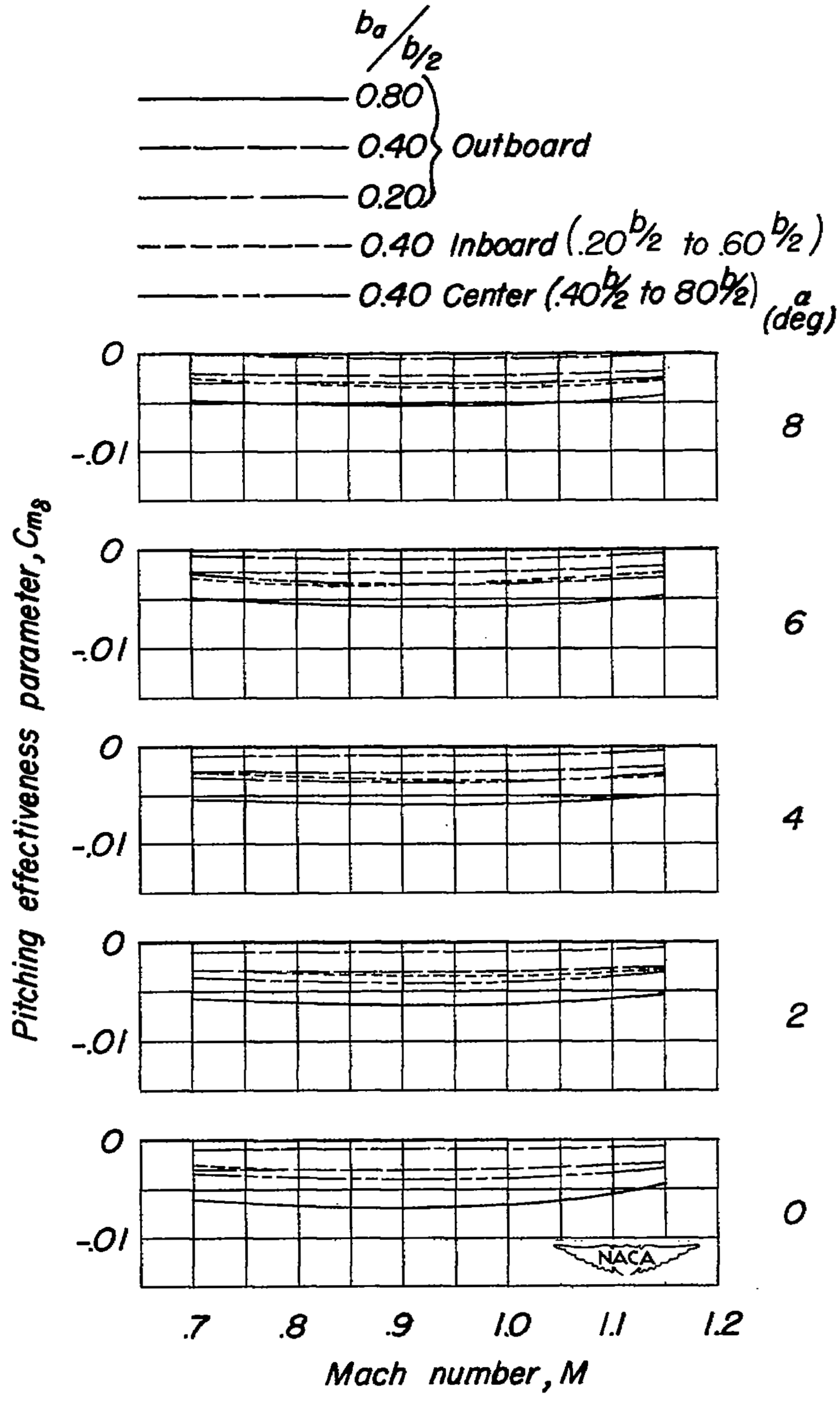


Figure 8.- Variation of pitching-effectiveness parameter with Mach number for flap-type controls on a 60° sweptback wing with aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil.

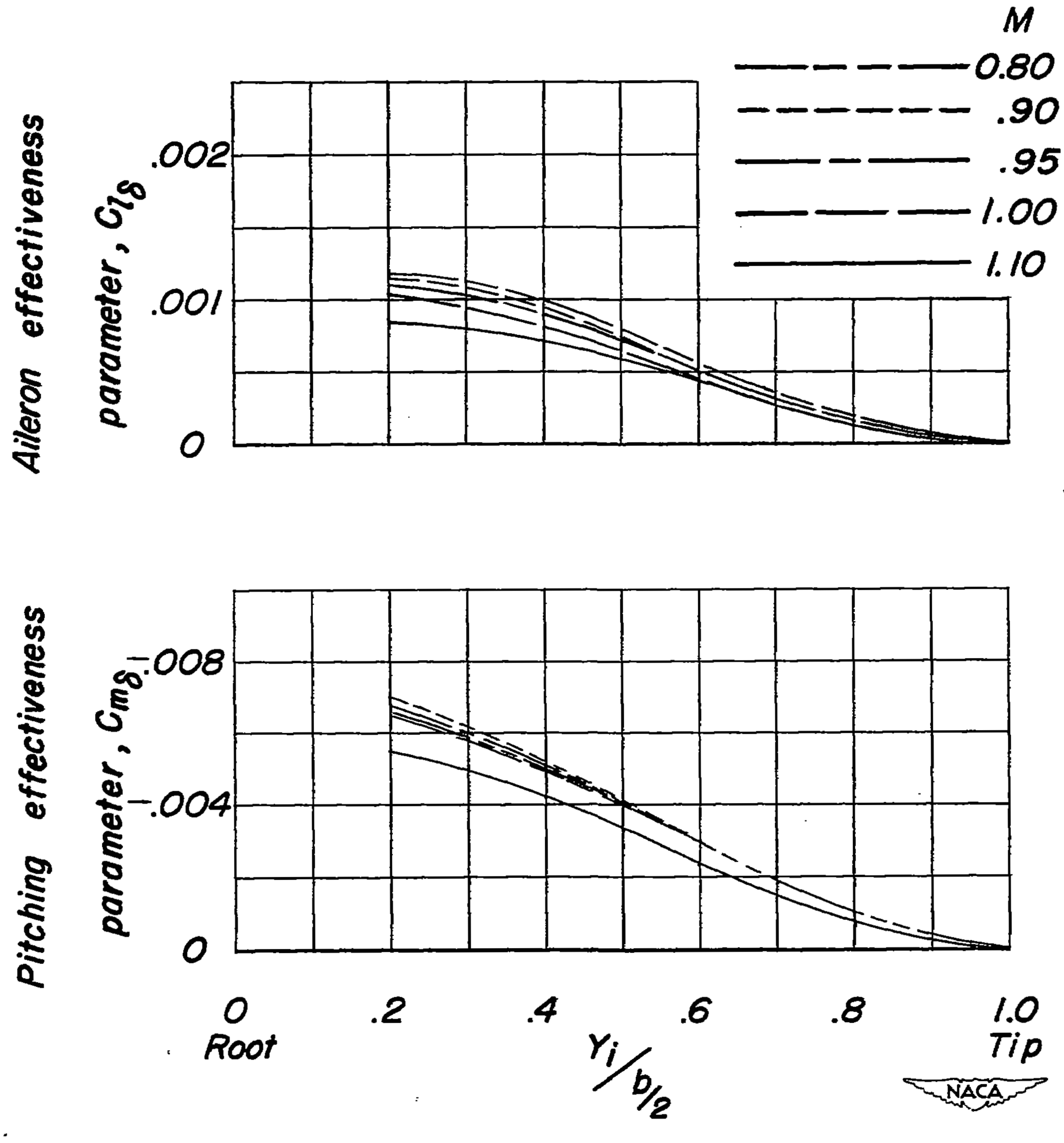


Figure 9.- Variation of control-effectiveness parameter with control span at various Mach numbers for flap-type controls on a 60° sweptback wing with aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil. $\alpha = 0^\circ$.

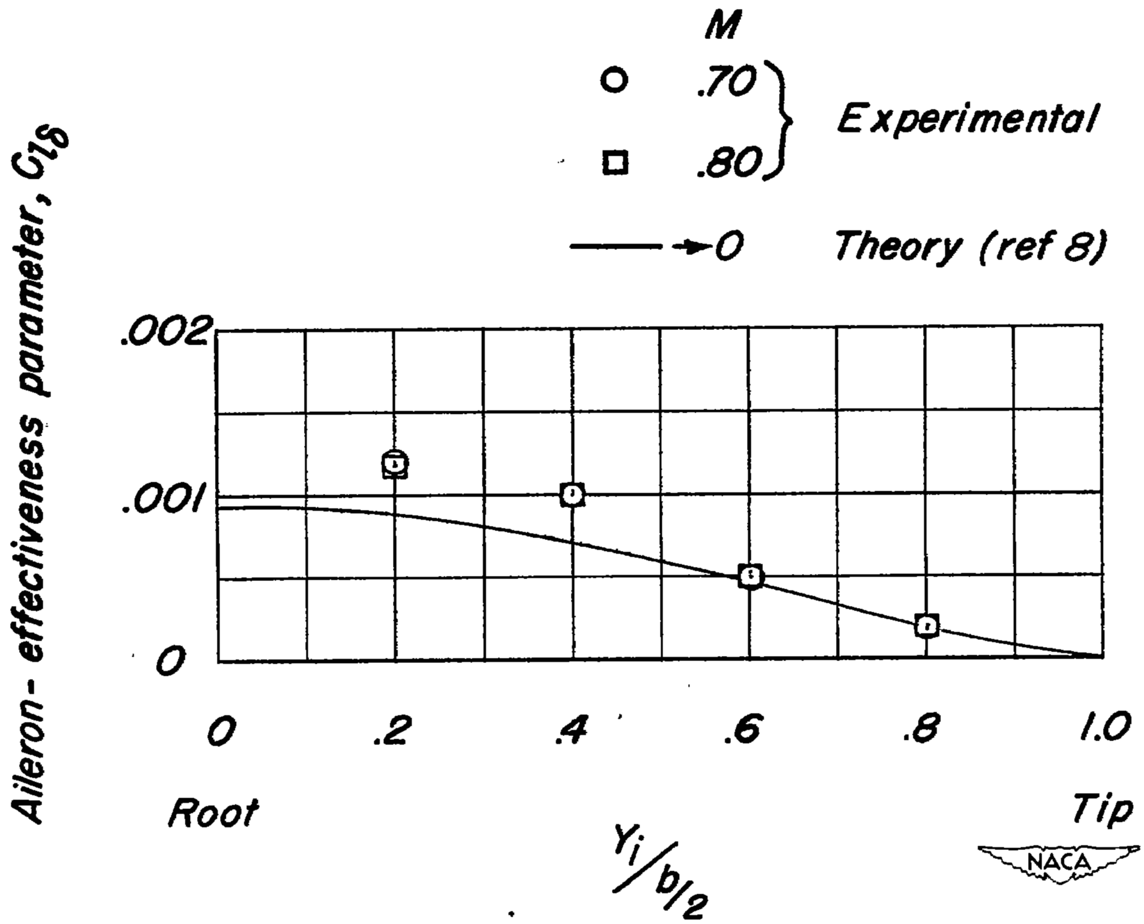


Figure 10.- Comparison of the experimental and estimated variation of aileron effectiveness with control span for flap-type controls on a 60° sweptback wing with aspect ratio 2, taper ratio 0.6, and NACA 65A006 airfoil. $\alpha = 0°$.

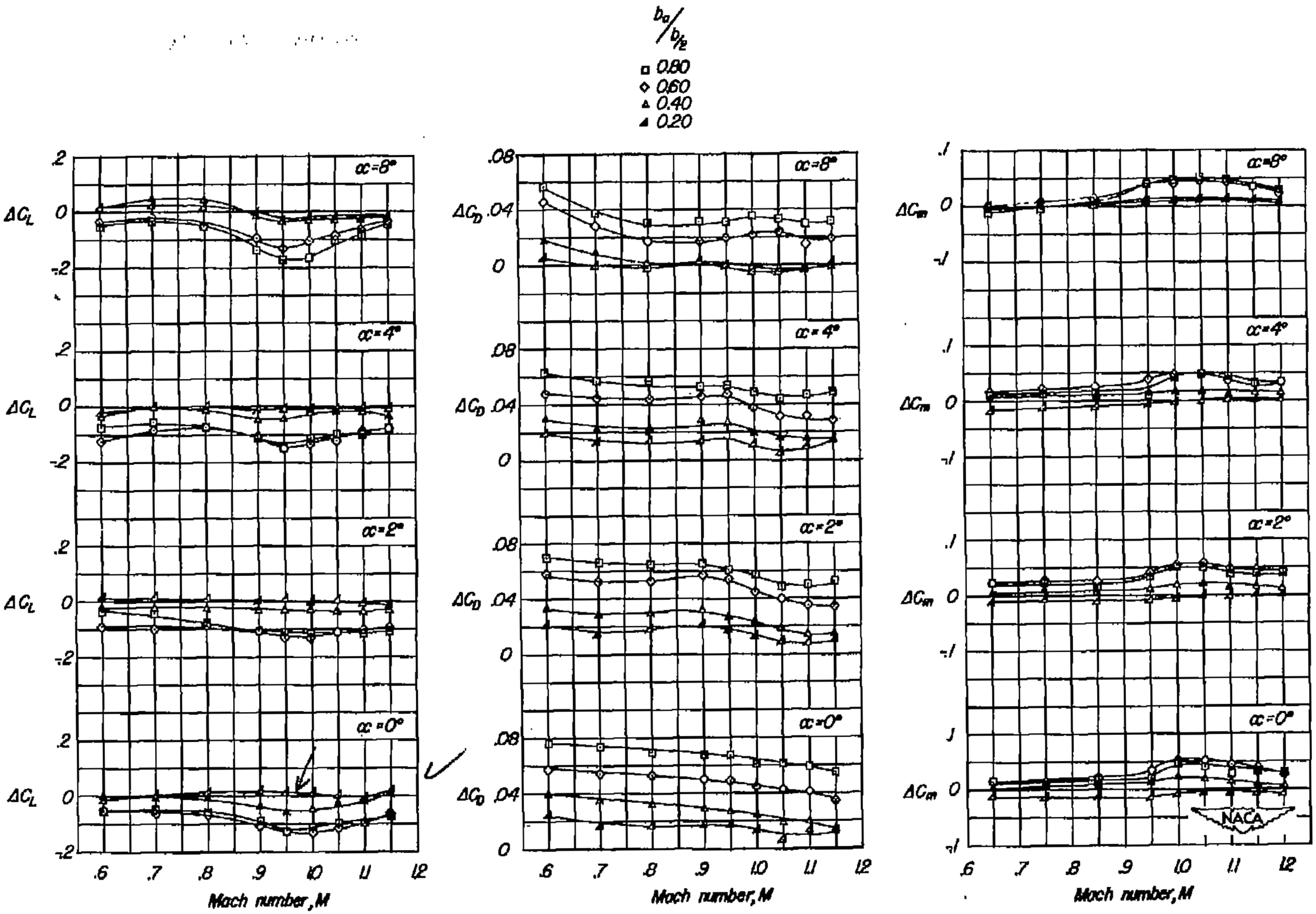


Figure 11.- Variation of incremental lift, drag, and pitching-moment coefficient of several outboard plain spoiler ailerons with Mach number. Projection = 0.05c.

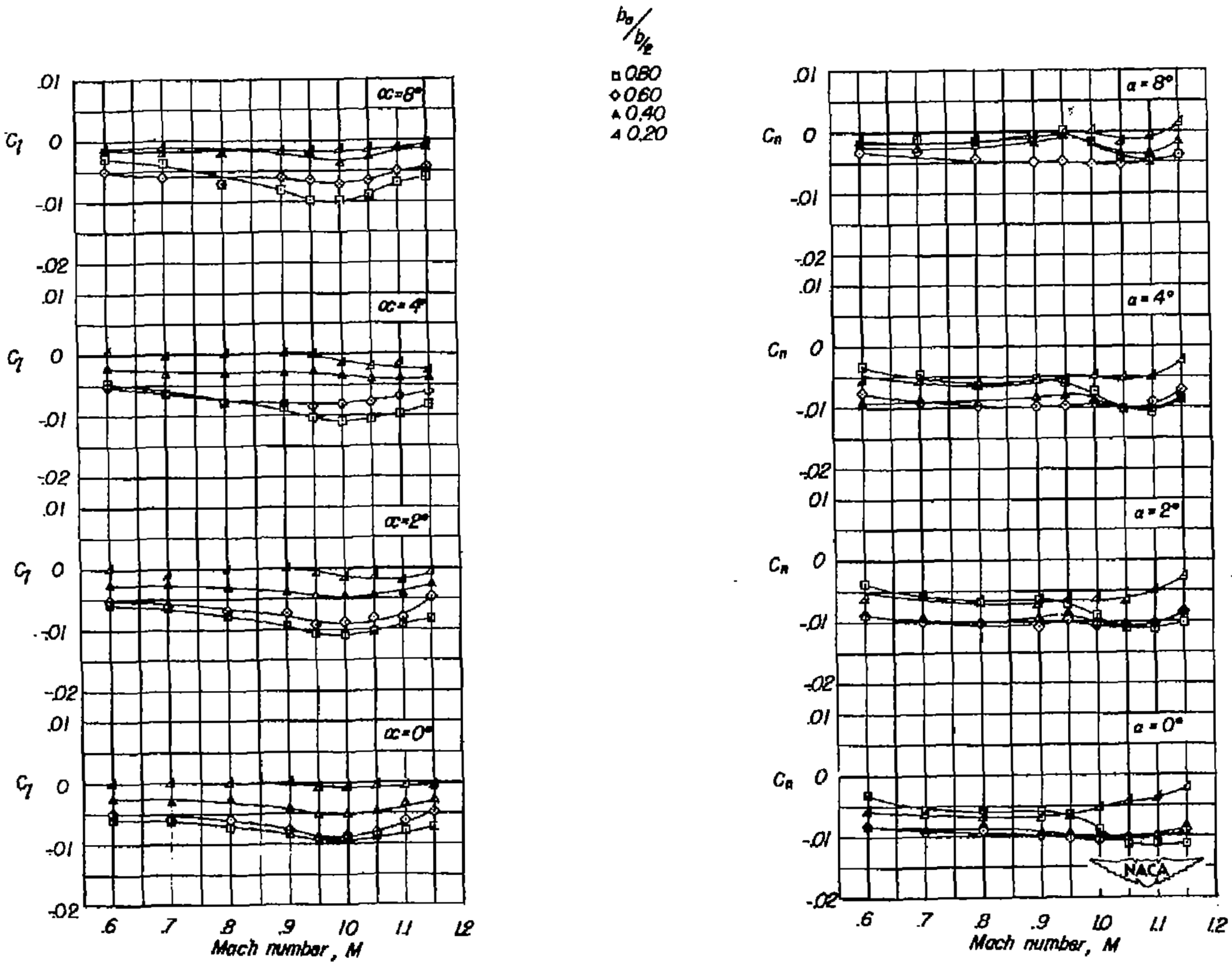


Figure 12.- Variation of rolling- and yawing-moment coefficients of several outboard plain spoiler ailerons with Mach numbers. Projection = 0.05c.

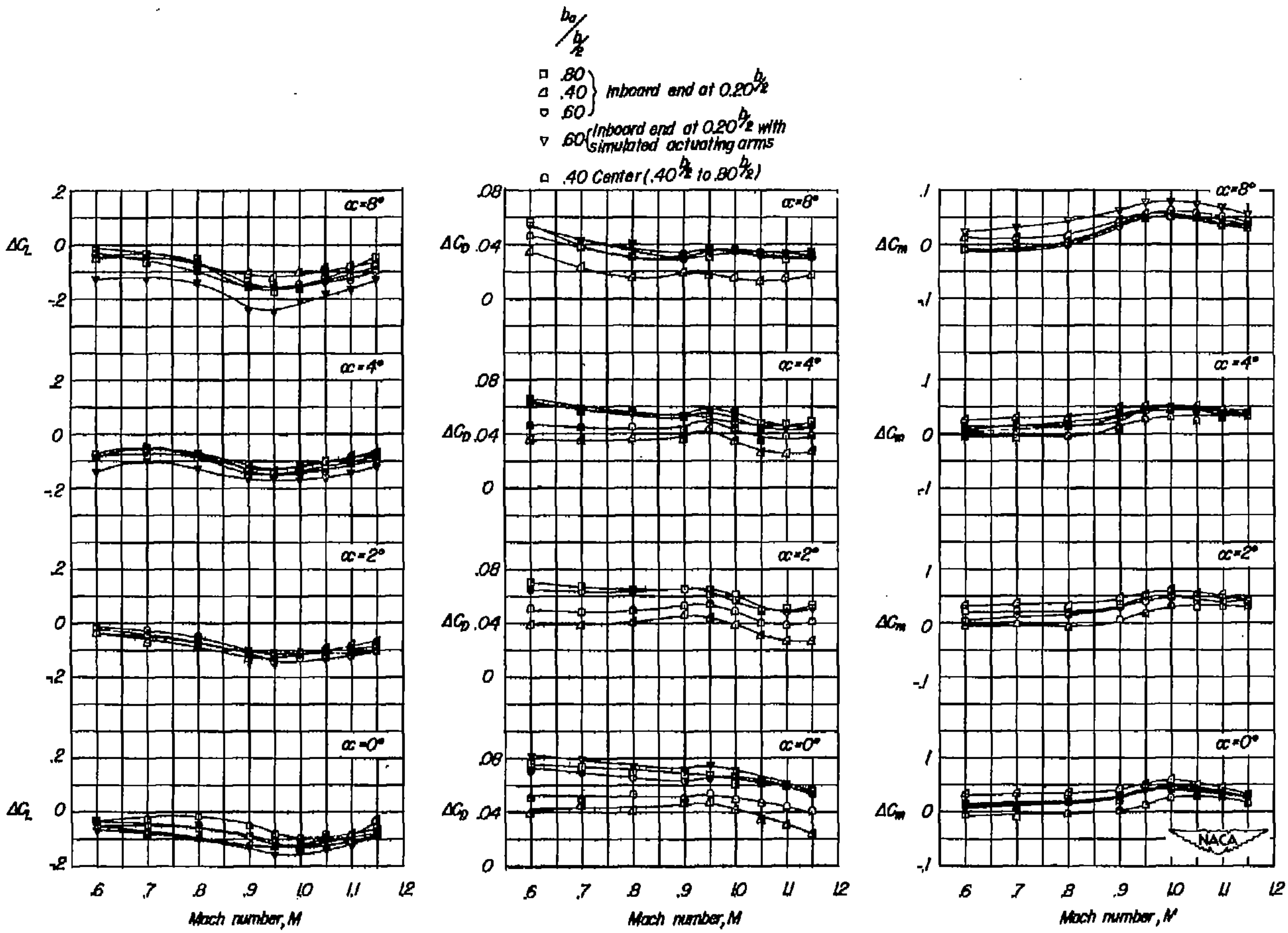


Figure 13.- Variation of incremental lift, drag, and pitching-moment coefficients of several inboard spoiler ailerons and a 0.40 center-span spoiler aileron with Mach number. Aileron projection = 0.05c.

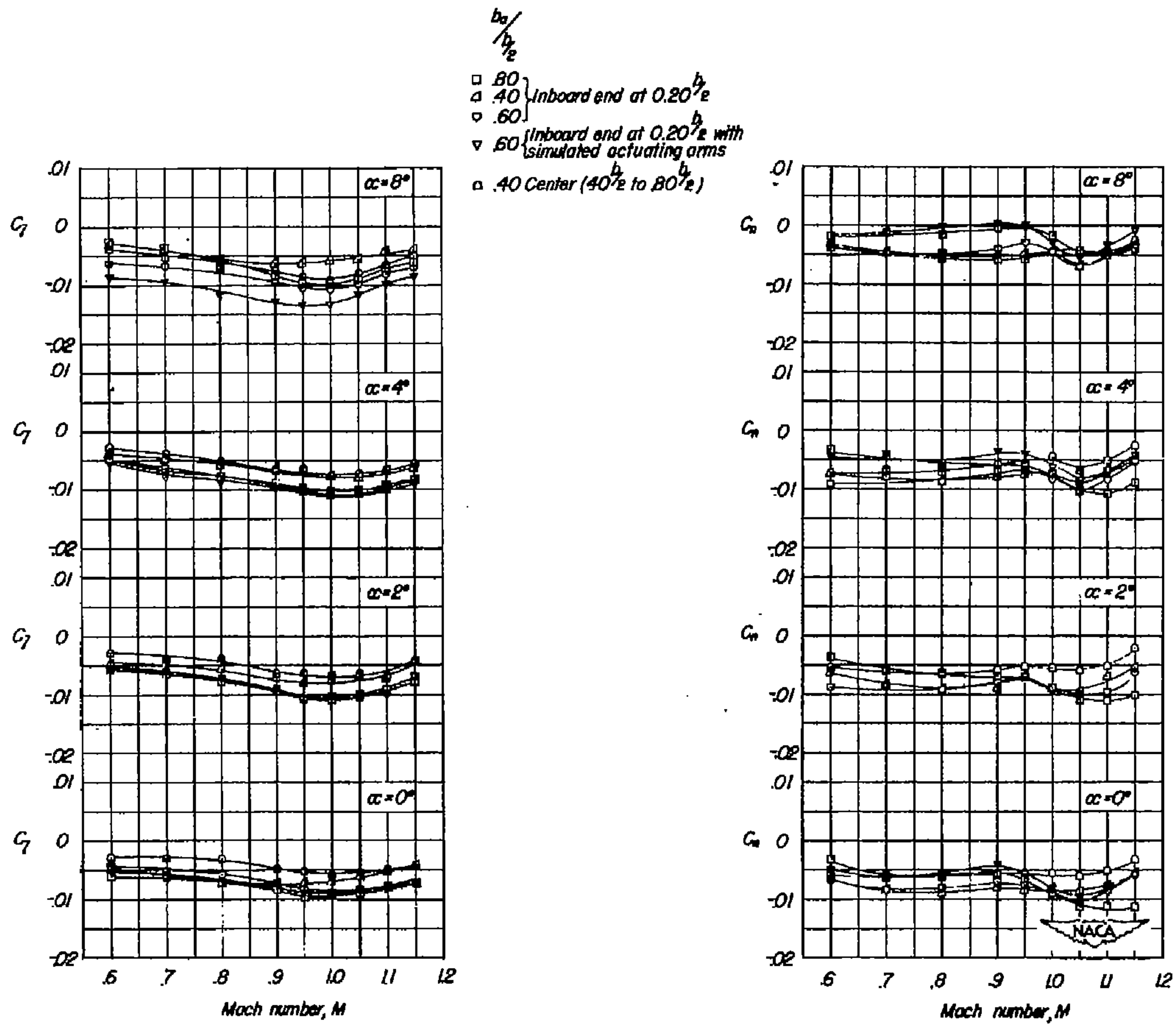


Figure 14.- Variation of rolling- and yawing-moment coefficients of several inboard spoiler ailerons and a 0.40 center-span spoiler aileron with Mach number. Projection = 0.05c.

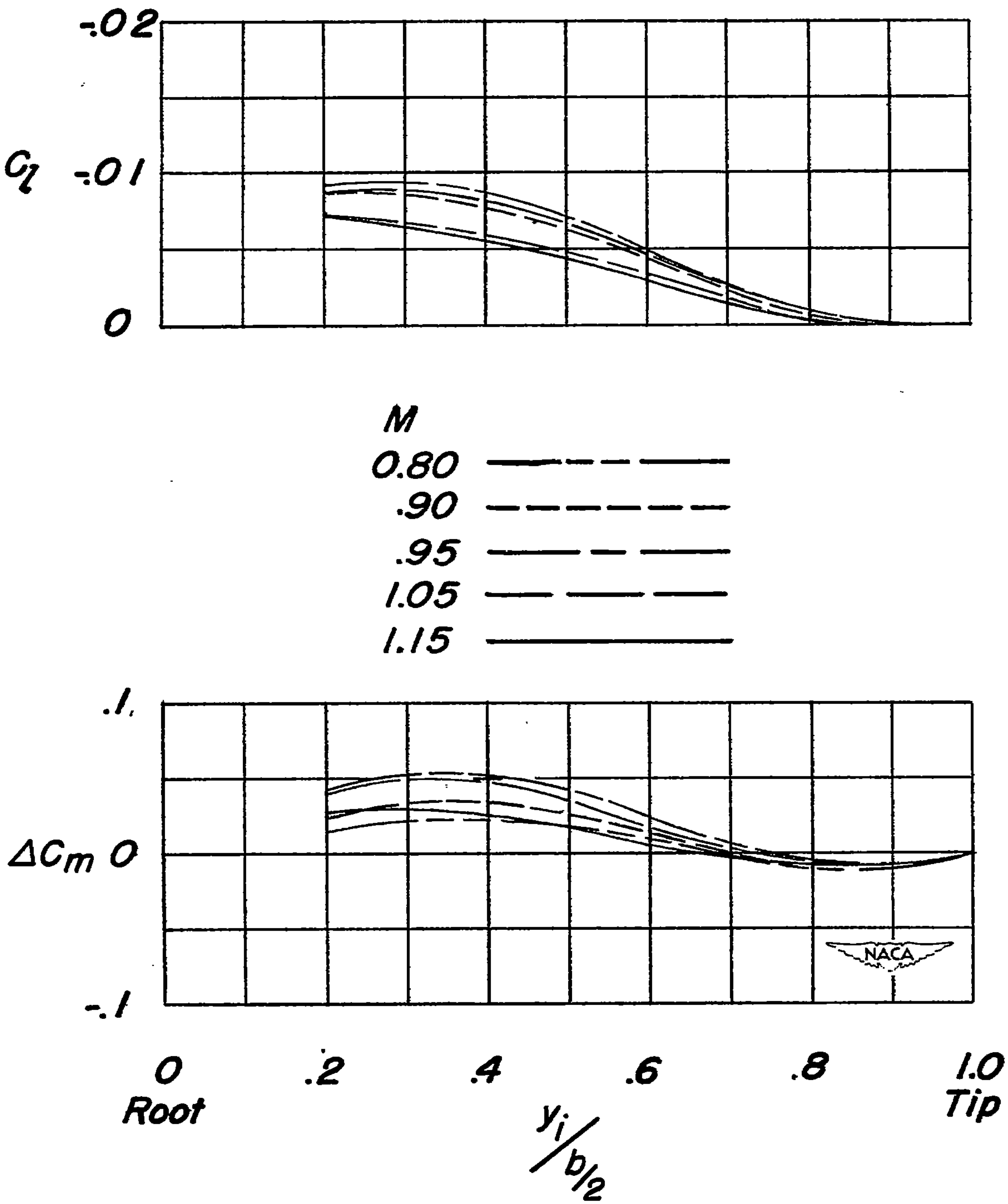


Figure 15.- Variation of rolling- and pitching-moment coefficients with spoiler-aileron span for several Mach numbers. $\alpha = 0^{\circ}$, spoiler projection = 0.05c.

[redacted]

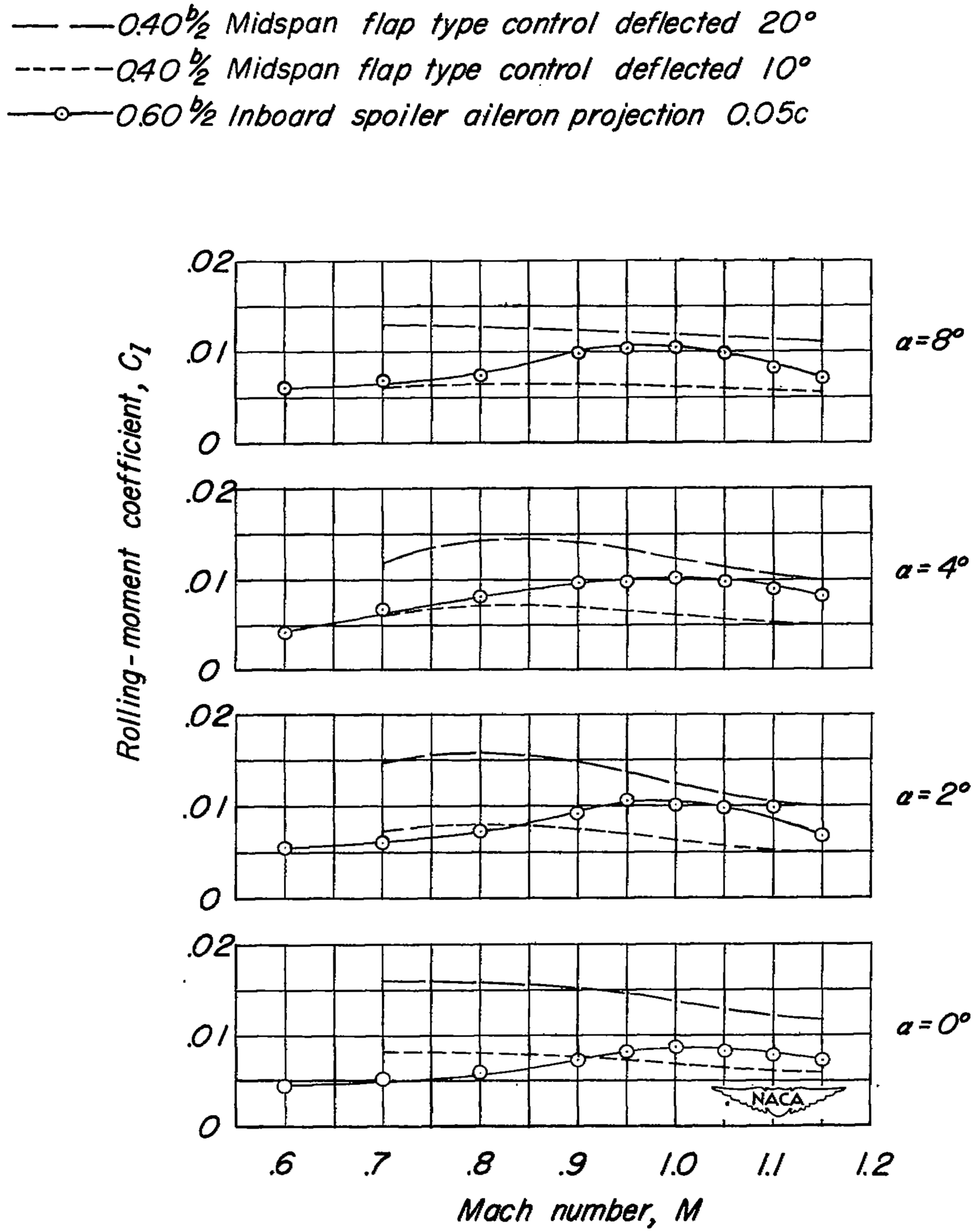


Figure 16.- Variation of rolling-moment coefficient with Mach number for a midspan $0.40\frac{b}{2}$ flap-type control deflected either 10° or 20° and an inboard $0.60\frac{b}{2}$ spoiler aileron projected 0.05c.